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ABSTRACT

Attractiveness of frontalin and constituents of resin were compared to Douglas-fir sections infested with unmated female Douglas-fir beetles [*Dendroctonus pseudotsugae* Hopk. (Coleoptera: Scolytidae)]. Four times more beetles responded to log sections infested with female beetles than to the next best treatment, a combination of frontalin and resin. When frontalin was combined with either resin, or most of its monoterpenes, a synergistic effect occurred. Equal numbers of male and female Douglas-fir beetles were attracted to resin and monoterpenes; the addition of frontalin to them resulted in catches of 2 to 4 males per female. Three species of predators and 23 species of other bark beetles were caught, mostly in a study area containing felled trees. Numbers of predators and bark beetles did not differ significantly by treatment but sex ratios of some species favored females. Included among bark beetles caught was a new species of *Hylurgops*, females of which were attracted to a log section containing female Douglas-fir beetles. Applied to live trees, the attractive treatments may be sufficient to induce attacks by wild Douglas-fir beetles. Use of attractants on mechanical traps instead of trees would be enhanced by the additional attractants apparently present in infested logs.

Introduction

The Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk. (Coleoptera: Scolytidae)) is one of several destructive bark beetles in the Western United States. It usually breeds in damaged trees, but periodically amasses great numbers and kills millions of board feet of mature Douglas-fir timber (Furniss and Orr 1970). Prevention of outbreaks might be achieved by either stand sanitation (destruction or removal of attractive host material such as windthrow) or logging of mature and overmature trees (Furniss 1959); but neither action is practical in the remote and extensive areas that are typical of the beetle's range. Trap trees (live trees felled to attract beetles) have been suggested for controlling the beetle, but their effectiveness has not been demonstrated. Such trees tend to be inefficient trappers of beetles because beetles usually attack felled trees in low density, and avoid the sun-lighted parts of the stem. Also, cutting of trap trees prior to beetle flight in the spring is difficult because of adverse weather and inaccessibility. Where recreation and watershed values are paramount, use of trap trees might be more destructive than beneficial. Insecticides are effective in killing broods in felled trees (Gibson 1957; Rudinsky, Terrier and Allen 1960) or preventing attacks (Furniss 1962), but these methods are uneconomical or undesirable to use in most instances.

Because of the great economic loss caused by the beetle and lack of a generally applicable means of regulating populations of beetles that cause it, we have turned our attention to development and use of chemical attractants produced by host trees and beetles. If determined to be effective, selective, and economical, these attractants would lend flexibility to the integrated courses of action available to resource managers in protecting susceptible Douglas-fir stands.

Attraction Literature

One of us (Furniss) demonstrated in 1959 that live Douglas-fir trees baited with fresh-cut slabs containing feeding female beetles were attacked by wild beetles (U.S. Forest Service 1960). McMullen and Atkins (1962) found that logs infested with female Douglas-fir beetles were more attractive than either uninfested logs or logs containing both female and male beetles. The theory has been advanced that monoterpenes of Douglas-fir resin serve as host attractants for the first (pioneer) beetle attack (Rudinsky 1966a). Also, it is known that pheromones secreted during the early stages of attack by female beetles greatly increase the attraction and result in aggregation and mass attack by additional beetles of both sexes. Such mass attack in a confined time period may be helpful to the beetles in overcoming resistance of live trees.

The monoterpenes of Douglas-fir wood resin include α-pinene, camphene, β-pinene, myrcene, 3-carene, and limonene (Hanover and Furniss 1966); α-pinene is by far the most abundant; however, camphene is present in minute amounts. Heikkenen and Hrutfiord (1965) reported that α-pinene attracts, but β-pinene repels, Douglas-fir beetles; and they hypothesized that proportions of these two monoterpenes in trees may determine which trees are attacked. Rudinsky (1966b) observed that solutions of ethyl alcohol and α-pinene, camphene, limonene, and raw resin attracted more Douglas-fir beetles than did an uninfested log; β-pinene and myrcene were relatively unattractive.

Pitman and Vité (1970) reported that frontalin (a pheromone found in several *Dendroctonus* species) and camphene are involved in the aggregating mechanism of the Douglas-fir beetle. Their discovery prompted us to compare the attractiveness of frontalin, six monoterpenes, resin, and log sections infested with unmated female beetles (♀logs) simultaneously in replicated field tests. Such information was sought to aid us in selecting the most attractive materials for future assessment of their value in aggregating wild beetles for control or survey purposes. Comparison of synthetic attractants (frontalin and monoterpenes) with the natural attractant provided by the female infested logs would also indicate whether additional attractants were likely to occur in the latter. We also were interested in the attractiveness of these materials to predacious insects and other species of bark beetles that might be in flight in the experimental area. Results of these field tests are reported here.

Methods

Tests were conducted between May 21 and June 2, 1970, on various sites in Boise Basin Experimental Forest near Idaho City, Idaho (table 1).

Treatments tested are listed in table 2. Purity of 0.2 µl samples of undiluted monoterpenes was checked at our laboratory by gas liquid chromatography (GLC) equipped with an electronic integrator. The column used was 6' of B, B' Oxydipropionitrile 15: 100 WAW. Monoterpenes were identified by their retention times.

Table 1.--*Characteristics of trapping locations in Boise Basin Experimental Forest, Idaho, 1970*

Location	Elevation	Aspect	Topography	Forest type	Estimated beetle population	Source of beetles
	Feet					
1. Slaughterhouse Gulch	4,100	E	Open ravine	[1]PP/DF	Medium	Scattered 1969-attacked trees nearby.
2. Bannock Creek	4,100	E	Ravine & bench	PP/DF	Heavy	Incoming beetles attracted to felled trees.
3. Bannock Creek	4,600-4,700	E	Lower slope	DF/PP	Heavy	Among 12-15, 1969-attacked trees.
4. Bannock Creek	5,000-5,200	N	Ravine	DF/PP	Light	None evident.
5. Bannock Creek	5,200-5,400	N	Mid-slope	DF/PP	Light to medium	Scattered 1969-attacked trees.

[1]PP = Ponderosa pine; DF = Douglas-fir.

Table 2.--*The number and sex of Douglas-fir beetles caught and treatment used, Boise Basin Experimental Forest, Idaho, 1970*

Treatment[1]	May 21			May 22			May 24			May 25			May 26			June 2			Total			
	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	
GROUP I[2]																						
1. Camphene										4		4	1	2	3	1	1	2	6	3	9	
2. Limonene										2	3	5	1	2	3		1	1	3	6	9	
3. α-pinene											1	1	1	3	4		1	1	1	5	6	
4. β-pinene													4	2	6				4	2	6	
5. Mixture B				1		1				3		3		1	1				4	1	5	
6. Resin													1	2	3	1		1	2	2	4	
7. Myrcene											2	2	1	1	2				1	3	4	
8. Mixture A		3	3											1	1					4	4	
9. 3-carene													2	1	3				2	1	3	
10. Mixture C				1		1										1		1	2		2	
TOTAL		3	3	2		2				9	6	15	11	15	26	3	3	6	25	27	52	
GROUP II[3]																						
11. Frontalin + resin	6	8	14		3	3	6	16	22	1	3	4	22	50	72	26	40	66	61	120	181	a[5]
12. Frontalin + α-pinene		1	1							2		2	26	52	78	6	16	22	34	69	103	b
13. Frontalin + limonene							4	10	14	2	1	3		2	2	7	5	12	13	18	31	b
14. Frontalin + myrcene							1	1	2				6	7	13	2	3	5	9	11	20	b c
15. Frontalin + β-pinene								3	3				2	6	8	3	4	7	5	13	18	b c
16. Frontalin + Mix. B				1		1		1	1	3		3	1	5	6	1	3	4	6	9	15	b c
17. Frontalin + Mix. C								2	2					10	10		1	1		13	13	b c
18. Frontalin + Mix. A					2	2		5	5	2	2	4	1	1	2				3	10	13	b c
19. Frontalin + camphene													1	2	3		2	2	1	4	5	c
20. Frontalin + 3-carene							2		2		2	2		1	1				2	3	5	c
TOTAL	6	9	15	1	5	6	13	38	51	10	8	18	59	136	195	45	74	119	134	270	404	
GROUP III																						
21. 50 ♀♀ in log	6	4	10	30	125	155	1	2	3	162	221	383	110	136	246	14	17	31	323	505	828	d
22. Frontalin[4] + resin	1	7	8	8	34	42		1	1	10	17	27	2	6	8	22	103	125	43	168	211	e
23. Frontalin + α-pinene[4]				22	44	66	1	6	7		10	10	1	3	4	3	26	29	27	89	116	e f
24. Frontalin + Mix. D[3]	1	6	7	5	20	25	2	2	4	2	6	8	5	23	28	6	16	22	21	73	94	e
25. Frontalin + Mix. D[4]		1	1	4	6	10	1	7	8	14	25	39		4	4	7	25	32	26	68	94	e
26. Frontalin + camphene[4]				4	7	11					2	2	1	1	2	9	60	69	14	70	84	f
27. Frontalin[3]					4	4					3	3				4	9	13	4	16	20	g
28. α-pinene[4]				2	2	4				1	2	3					1	1	3	5	8	h
29. Camphene[2]				1	2	3								2	2				1	4	5	h
30. Check																						
TOTAL	8	18	26	76	244	320	5	18	23	189	286	475	119	175	294	65	257	322	462	998	1,460	
GRAND TOTAL																			621	1,295	1,916	

[1]A = α-pinene + camphene + limonene
B = β-pinene + myrcene + 3-carene
C = all 6 monoterpenes
D = α-pinene + camphene

[2]Supplier: Chemical Samples Co. (CSC)

[3]Frontalin supplied by Boyce Thompson Institute, monoterpenes by CSC.

[4]Supplier: Stanford Research Institute.

[5]Totals having unlike, single, alphabetical designations differ at the 0.5 level. Comparisons not valid between groups.

Log sections (fig. 1A) were infested with female beetles nightly for the first three replications, but later tests employed log sections infested up to 7 days previously. Monoterpenes and frontalin were kept refrigerated as much as possible prior to placement in the field. They were delivered by diffusion to the air by two methods: (1) 1.8-ml. capacity polyethylene plastic stoppers[1] (fig. 1B); and (2) inverted 1-oz. capacity glass jars, the lids of which were perforated; inside these jars, the $\frac{1}{2}$-dr. glass vials containing the candidate attractants were open and in an upright position (fig. 1C). Resin was collected from cut faces of a single live tree daily in 1-dr. open vials from which odors were dispersed. Approximate amounts of chemicals dispensed into plastic stoppers per replicate were: frontalin, 10 mg.; camphene, 50 mg.; and monoterpenes, 0.6 ml. total (divided equally when more than one monoterpene was added). Amounts dispensed into glass vials per replicate were: frontalin, 10 mg.; camphene, 50 mg.; α-pinene, 20 mg.; and resin, 0.1-0.2 ml.

Approximately 5 mg./hr. of frontalin is diffused from plastic stoppers under field conditions conducive to beetle flight (Dr. G. B. Pitman, personal communication). At 6,000 feet elevation and 73° F., 1 mg./hr. of frontalin, α-pinene, or camphene (a solid) is diffused from glass jar dispensers; at 88° F. the rate is increased to 2 mg./hr. (Dr. J. O. Rodin, personal communication). The number of female equivalents represented by these delivery rates is unknown. It has been suggested that mass aggregation of the western pine beetle, *Dendroctonus brevicomis* Lec., requires a concentration of frontalin 10 times that produced naturally by attacking beetles (Vité and Pitman 1970).

The attractant-containing delivery units (log sections, stoppers, and bottles) were attached to $\frac{1}{4}$-inch mesh wire screen traps to which Stickem Special had been applied with a paint roller (fig. 2). The cylindrical screen traps were 4 feet long and 15 inches in diameter and were mounted vertically on $\frac{7}{8}$-inch diameter, 6-foot-long water pipes driven into the ground. Rigidity was provided by a circular support of $\frac{3}{8}$-inch plywood inside, near the middle of the cage. Wire stays extended across the top of the support through the screen and at the bottom of the cage running from the screen to the pipe. Traps were placed at distances varying from approximately 75 to 150 feet apart; the intention was to avoid such closeness that intermingling of odors from adjacent traps might affect beetle response.

The plastic stoppers were held to cages by spring-type paper fasteners hung on wire hooks (fig. 1B). Jars, held to traps by wires, were covered with aluminum foil to reflect heat (fig. 1C). Stoppers and jars were fastened on the outside of cages for convenience and positioned in the shade of the plywood shelf to slow evaporation of attractants. Female logs in the traps were placed inside open paper bags to avoid frass contaminating the plywood shelves on which they rested (fig. 1A).

Each of the 30 treatments was applied daily for 6 days, a total of 180 trap days. Because it was physically impossible to fit all 30 traps 75-150 feet apart in some restricted test locations, we divided the traps and treatments into 3 groups of 10 each. Thus, it took 3 days to test each treatment once at a location. This formed 2 (3 by 3) Latin Squares for the effect of test location and test period. Within the study areas, treatments were assigned to traps at random. After 30 treatments had been applied, traps were moved to new locations, except for Location 2 where traps were left for 6 days.

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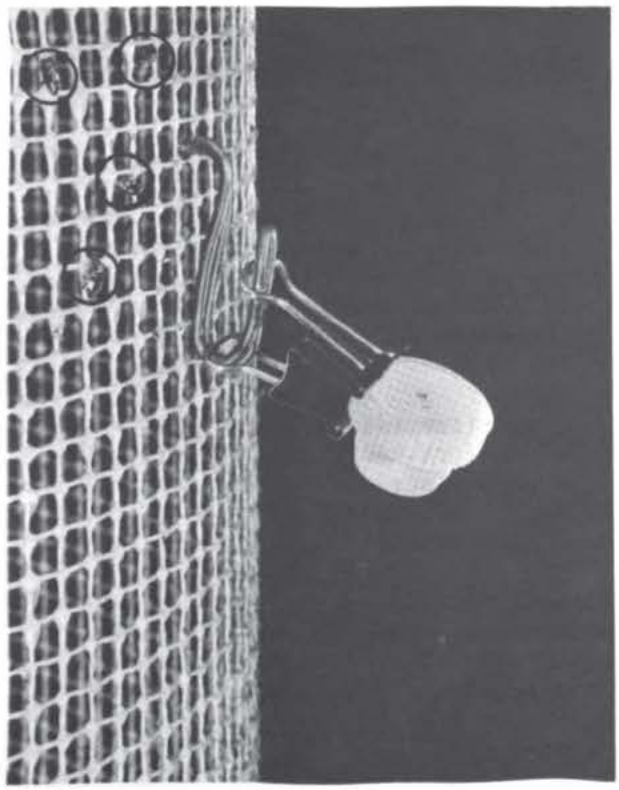
[1]Polyethylene closed bottom stoppers with polyethylene top inserts for 3-dr. vials, No. 10-5945. Ace Scientific Supply Co., Inc., 1420 E. Linden Ave., Linden, New Jersey 07036.

Figure 1.--Methods of delivering substances tested for relative attractiveness to the Douglas-fir beetle and associated insects (circles indicate trapped beetles): A, Stem section infested with 50 unmated female beetles (paper bag removed); B, hollow polyethylene plastic stopper; C, glass jar with perforated lid and vials inside (aluminum foil cover removed).



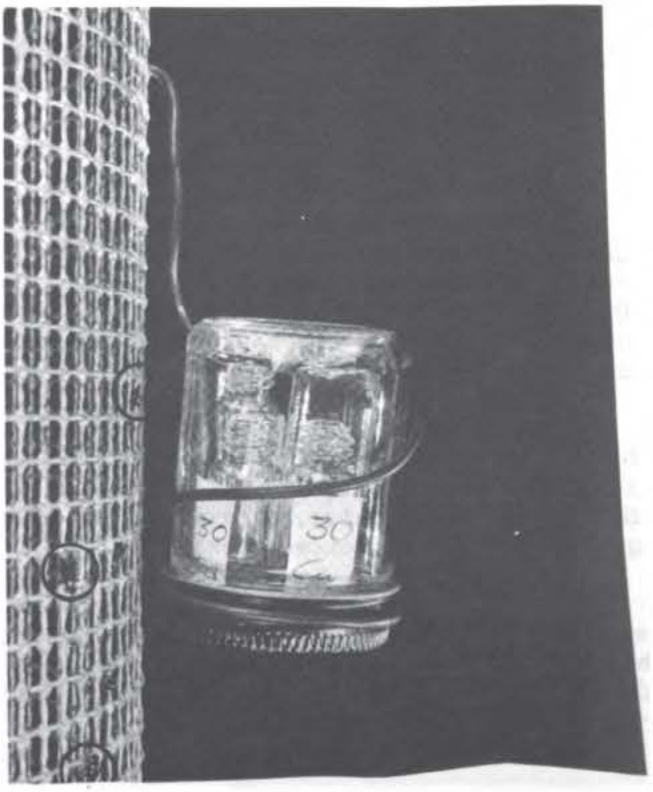


Figure 2.--Wire screen sticky trap used to catch beetles during tests of the attractiveness of derivatives of Douglas-fir resin, frontalin, and stem sections infested with female beetles.

Numbers of Douglas-fir beetles caught were subjected to analysis of variance using unweighted means (table 3). The criterion used in the analysis was the transformed counts of insects caught by species. Counts were transformed by the $\log_e$ of counts + 0.5 to stabilize variance due to zero counts. Other abundant species (predators and other bark beetles) were analyzed similarly, using Location 2 data only, due to scarcity of these species elsewhere.

Each day's catch of Douglas-fir beetles, predators (clerids, ostomids) and other bark beetles was removed during the following morning before additional insects began flying. To dissolve the Stickem Special, specimens were placed in labeled vials of Shell solvent. Later, specimens were removed, dried, and stored in alcohol for subsequent identification and sexing.

After ridding a trap of beetles, the old bait was removed and replaced by another, assigned at random. Thus, although a bait was present on a trap for nearly 24 hours, beetle flight occurred almost entirely between noon and dark when temperatures were favorable. Tests were not conducted on stormy days or when air temperature did not reach approximately 65° F.

Table 3.--*Analysis of variance of total number of Douglas-fir beetles caught by baited traps at Boise Basin Experimental Forest, 1970*

Source	df	S.S.[2]	M.S.	F
Squares	1	43.540	43.540	43.453**
Periods/square	4	13.084	3.271	3.264
Locations/square	4	47.156	11.789	11.765**
Groups of attractants	2	68.394	34.197	34.129**
Error (a)	6	6.015	1.002	
Treatments per group	27	157.383	5.829	6.992**
Error (b)	135	112.550	.834	
K/location/square[1]	54	60.318	1.117	1.734*
Error (b')	81	52.177	.644	
Total	179	448.122		

[1]Variation from individual trap (K) position within a location within a square after adjustment for treatment and group.

[2]Sums of squares are based on the $\log_e$ (total number beetles + 0.5).

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Results and Discussion

PURITY OF MONOTERPENES

Host tree-produced monoterpenes appear to have two roles in bark beetle attraction; some synergize the attractiveness of pheromones while others may mask their attractiveness. In either case, presence of unwanted monoterpenes as contaminants might affect results. Gas chromatograms of the commercial monoterpenes used in our tests indicated the presence of appreciable amounts of impurities in all but camphene and limonene. Retention time of limonene was greater than anticipated (similar to terpinolene), but the manufacturer confirmed that a sample from the same batch was limonene. Impurities in the α-pinene included camphene and β-pinene; interestingly, these two chemicals occurred in proportions similar to raw Douglas-fir wood resin (Hanover and Furniss 1966). The β-pinene appeared to have minor amounts of α-pinene, camphene, and probably myrcene. The 3-carene had appreciable amounts of impurities (confirmed by the manufacturer), retention times of which indicated presence of α-pinene, β-pinene, myrcene (mostly), limonene, and an unknown. The myrcene appeared to contain some camphene and β-pinene.

The purity as labeled by manufacturer is followed by our determination of purity: α-pinene (90-73), camphene (99-98), β-pinene (95-92), myrcene (96-91), 3-carene (96-73), and limonene (98-95). We did not assess the effect of impurities on response of beetles to these materials during our tests.

RESPONSE OF DOUGLAS-FIR BEETLES

The kinds and relative abundance of scolytids and predators caught by traps are shown in table 4. The Douglas-fir beetle was the most abundant species caught, followed by *Ips pini* (Say), *Hylastes* spp., *Enoclerus sphegeus* Fab. and *Dendroctonus valens* Lec., which are discussed later.

Table 4.--*Species and numbers of beetles caught by sticky traps, combined treatments*

Species	Number ♀	Number ♂	Total
Dendroctonus pseudotsugae Hopk.	621	1,295	1,916
Predators			
Enoclerus sphegeus (Fab.)	133	180	313
Temnochila virescens chlorodia (Mann.)	17	14	31
Thanasimus undatulus Say	11	7	18
Other bark beetles			
Ips pini (Say)	221	208	429
Dendroctonus valens Lec.	71	111	182
Hylastes nigrinus (Mann.)	70	85	155
Hylastes macer Lec.	75	53	128
Hylurgops porosus (Lec.)	77	9	86
Hylurgops n.sp.	47	8	55
Hylastes gracilis Lec.	16	14	30
Pityogenes carinulatus (Lec.)	10	12	22
Orthotomicus latidens (Lec.)	4	12	16
Hylurgops subcostulatus (Mann.)	11	1	12
Hylurgops ruber Sw.	9	1	10
Pityopthorus confinis Lec.	5	5	10
Dendroctonus brevicomis Lec.	3	4	7
Pseudohylesinus nebulosus (Lec.)	4	3	7
Gnathotrichus retusus (Lec.)	4	2	6
Hylastes longicollis Sw.	3	3	6
Scolytus fiskei Blackman	4	2	6
Scolytus unispinosus Lec.	2	1	3
Orthotomicus caelatus (Eichh.)	1	1	2
Trypodendron lineatum (Oliv.)	1	1	2
Dendroctonus ponderosae Hopk.	1		1
Hylurgops rugipennis (Mann.)	1		1
Ips emarginatus (Lec.)	1		1
TOTAL	1,423	2,032	3,455

Catch by Treatments

Numbers of Douglas-fir beetles caught by treatment, date, and sex are shown in table 2. The response of beetles to treatment differed markedly. Group I treatments (resin and monoterpenes) caught one-eighth as many beetles as Group II treatments (frontalin added to resin and monoterpenes). Comparison with the catch of frontalin alone (see Group III treatments, table 2) indicates that a synergistic effect occurred when frontalin was combined with resin or some of its constituent monoterpenes. The most attractive of these combinations was frontalin and resin followed by frontalin and α-pinene. Curiously, frontalin and camphene, reported by Pitman and Vité (1970) to be nearly seven times more attractive than 25 female beetles feeding in Douglas-fir log sections, were less attractive than all but one of the other Group II treatments. When deployed among our Group III treatments (including a ♀ log) frontalin and camphene caught the second highest number (69) of beetles during one replication (June 2), but the total trapped (84) was still significantly less than the other combinations of Group III. However, by testing that particular ♀ log in another area the next day, we confirmed that it had lost most of its attractiveness. Lack of competition from an attractive ♀ log seems involved in the relatively high catch (mostly males) by frontalin and camphene on June 2.

Outstanding among treatments was the total catch by ♀ log traps which was nearly 4 times that of frontalin plus resin and nearly 7 times that of frontalin plus α-pinene, the second and third best treatments, respectively. We interpret this to indicate that the ♀ logs contained attractants not included in our other treatments. That is, even raw resin plus frontalin apparently lacked some attractants contained in the ♀ logs. We suspect that the additional attractants in the logs are contributed by the ♀ beetles, rather than their host. The presence of additional pheromones has also been inferred by Pitman and Vité (1970).

Sex Ratios of Beetles

Approximately equal total numbers of ♂ and ♀ beetles were attracted to resin and its monoterpene constituents (table 2, Group I treatments). Addition of frontalin to those materials (Group II) resulted in an overall male/female ratio of about 2:1. When ♀ logs were present among the treatments (Group III), the sex ratios of beetles responding to comparable treatments involving frontalin were generally higher, attaining 4:1 for frontalin and resin (No. 22, table 2). These results differ from those of Pitman and Vité (1970) who reported generally more females responding.

Compiled in table 5 are total numbers of Douglas-fir beetles and ratios of males to females attracted to resin or monoterpenes alone, and with frontalin added. These data differ from table 2 by including six additional replications of some treatments that were set out in competition with ♀ logs. The male/female ratios without frontalin and with frontalin were 1.2 and 2.7, respectively.

Numbers of beetles and sex ratios for six groups of treatments have been extracted from table 2 and appear in table 6. Sex ratios scale upward from near one for resin and monoterpenes alone to four for frontalin alone. Mixtures of the two attracted intermediate sex ratios.

Catch by Date

We examined felled trees for new beetle attacks, and then began our tests soon after beetles began emerging and flying. Maximum air temperatures and number of beetles caught by date are shown in table 7. Had all treatments been replicated daily at each location, numbers of beetles and air temperatures might have been correlated better.

Table 5.--*Sex ratios of Douglas-fir beetles attracted to resin and monoterpenes alone and with frontalin*

Treatment	Number and sex of beetles			
	Resin or monoterpenes alone		Frontalin added	
	Number	♂/♀	Number	♂/♀
Resin	4	1	391*	2.8
α-pinene	14*	2.5	219*	2.6
Camphene	12*	.7	89*	4.9
β-pinene	6	.5	18	2.6
Myrcene	4	3	20	1.2
3-carene	3	.5	5	1.5
Limonene	9	2	31	1.4
Mix. A[1]	4	All ♂	13	3.3
Mix. B[1]	5	.25	15	1.5
Mix. C[1]	2	All ♀	13	All ♂
Total or average	63	1.2	814	2.7

[1]See table 2 for composition of mixtures.

*12 replications; others, 6 replications.

Table 6.--*Sex ratios of species that were caught in greatest abundance by treatment*

Treatment	Trap days	Douglas-fir beetle		*Enoclerus sphegeus*		*Dendroctonus valens*		*Ips pini*	
		Number	♂/♀	Number	♂/♀	Number	♂/♀	Number	♂/♀
Resin	6	4	1	20	1	8	1	39	1.3
Monoterpenes (6)	66	59	1.2	126	1.1	58	1.1	129	1.0
Frontalin	6	20	4	7	6	1	1	33	.9
Resin & frontalin	6	391	2.8	15	1.1	6	2	27	.9
Monoterpenes (6) & frontalin	84	611	2.6	126	1.9	106	1.9	182	.8
♀ log	6	828	1.6	7	.75	3	2	3	.5
Check	6	0	--	12	1.0	0	--	16	1.7
Total	180	1,913	2.1	313	1.4	182	1.6	429	.9

Table 7.--*Relationship of maximum air temperature and number of Douglas-fir beetles trapped*

Date	Air temperature		Douglas-fir beetles caught	
	Idaho City 3,900 ft.	Location 2 4,100 ft.	Location 2	All areas
	------ °F. ------			
May 21	70	65	3	44
22	74	69	320	328
24	72	69	51	74
25	78	74	15	508
26	77	72	195	515
June 2	84	80	322	447

Table 8.--*Number of Douglas-fir beetles caught by treatment and delivery system*

Treatment	Delivery system: Polyethylene caps	Delivery system: Glass vials in jar
α-pinene	6	8
α-pinene + frontalin	103	116
Camphene	9	3
Camphene + frontalin	5	84
α-pinene-camphene, frontalin	94	94
Resin + frontalin	181	210
Total	398	515

Delivery System and Source of Attractants

Of the 28 artificial treatments (excluding the ♀ log and the check), 22 were delivered in polyethylene plastic stoppers; six were delivered in glass vials inside glass jars with perforated lids. Both delivery systems shared six treatments in common (see table 8).

Numbers of beetles caught were comparable with either delivery system. Although the glass vials seemed better for camphene and frontalin together, the difference may be due to some other factor. In subsequent tests, choice of delivery system should be dictated by practical considerations such as risk of breakage, spillage, and convenience. A screwcap polyethylene container would avoid leakage that occurred around the lid of some of the polyethylene bottle stoppers.

RESPONSE OF PREDATORS

Response by Treatment

Relatively few *Thanasimus undatulus* and *Temnochila virescens* were caught (table 9). Their numbers and sex ratios did not differ significantly by treatment. Most were trapped at Location 2 among felled trees. These two predators may have become more abundant after completion of our tests. This seems especially true of *T. undatulus* which one of us (Schmitz) is studying intensively.[2] In any case, our results do not indicate that any of the treatments are important in the aggregating mechanism of these predators.

[2]For doctoral thesis: The biosystematics of the North American species of *Thanasimus* Latreille (Coleoptera: Cleridae).

Table 9.--*Number and sex of* Thanasimus undatulus *and* Temnochila virescens *caught by treatment and date, Boise Basin Experimental Forest, Idaho, 1970*

Treatment[1]	May 22 ♀	May 22 ♂	May 22 Σ	May 24 ♀	May 24 ♂	May 24 Σ	May 25 ♀	May 25 ♂	May 25 Σ	June 2 ♀	June 2 ♂	June 2 Σ	Total ♀	Total ♂	Total Σ
Thanasimus undatulus															
Frontalin + Mix. D	3	2	5					1	1				3	3	6
3-carene	1		1										1		1
Frontalin + β-pinene				1	1	2							1	1	2
Frontalin + α-pinene					1	1				2		2	2	1	3
Frontalin + camphene										2	2	4	2	2	4
Frontalin + resin										1		1	1		1
Frontalin + limonene										1		1	1		1
TOTAL	4	2	6	1	2	3		1	1	6	2	8	11	7	18

Treatment	May 25 ♀	May 25 ♂	May 25 Σ	May 26 ♀	May 26 ♂	May 26 Σ	June 2 ♀	June 2 ♂	June 2 Σ	Total ♀	Total ♂	Total Σ
Temnochila virescens												
Mix. A		1	1								1	1
β-pinene	1	1	2							1	1	2
Limonene	3		3							3		3
Frontalin + α-pinene				1	1	2				1	1	2
Frontalin + myrcene				1		1				1		1
Frontalin + Mix. D								2	2		2	2
Camphene							6	3	9	6	3	9
♀♀ log								2	2		2	2
Check								2	2		2	2
Frontalin + camphene							3	2	5	3	2	5
Frontalin + resin							2		2	2		2
TOTAL	4	2	6	2	1	3	11	11	22	17	14	31

[1]See table 2 for composition of mixtures.

The number of trapped *Enoclerus sphegeus* held relatively constant throughout the tests (table 10). Little difference is apparent in their numbers caught by treatments. Sex ratio favored males in most treatments, especially those involving frontalin. Test location had a pronounced effect on catch (table 11). Location 2 accounted for 97 percent of all *E. sphegeus* caught. As noted previously, this area was uniquely different from the others by having been logged the previous winter. Among the traps were scores of merchantable ponderosa pine and Douglas-fir logs under attack by numerous bark beetles and wood borers before and during the tests. The down trees and insects infesting them apparently contributed somehow to the presence of this clerid.

Table 10.--*Number and sex of* Enoclerus sphegeus *caught by treatment, Boise Basin Experimental Forest, Idaho, 1970*

Treatment[1]	May 21			May 22			May 24			May 25			May 26			June 2			Total		
	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ	♀	♂	Σ
GROUP I																					
1. Camphene	1	2	3							1	2	3							2	4	6
2. Limonene	7	2	9							3	6	9							10	8	18
3. α-pinene	8	8	16							8	5	13							16	13	29
4. β-pinene	3	3	6							1	4	5							4	7	11
5. Mix. B	1	1	2							4	7	11							5	8	13
6. Resin	2		2							8	9	17					1	1	10	10	20
7. Myrcene	2	1	3							4	3	7							6	4	10
8. Mix. A	1		1							2	5	7							3	5	8
9. 3-carene	2	1	3							1		1							3	1	4
10. Mix. C	1	1	2							3	1	4							4	2	6
TOTAL	28	19	47							35	42	77					1	1	63	62	125
GROUP II																					
11. Frontalin + resin							1	1	2	1		1		3	3				2	4	6
12. Frontalin + α-pinene								3	3				2	5	7	1		1	3	8	11
13. Frontalin + limonene							4	3	7		1	1	3	6	9				7	10	17
14. Frontalin + myrcene							2		2				1	4	5				3	4	7
15. Frontalin + β-pinene							2	3	5	1		1	2	6	8				5	9	14
16. Frontalin + Mix. B							1	3	4				1		1				2	3	5
17. Frontalin + Mix. C							9	2	11										9	2	11
18. Frontalin + Mix. A							2	2	4		1	1		2	2				2	5	7
19. Frontalin + camphene								1	1					4	4		1	1		6	6
20. Frontalin + 3-carene							1	7	8		1	1							1	8	9
TOTAL							22	25	47	2	3	5	9	30	39	1	1	2	34	59	93
GROUP III																					
21. 50 ♀♀ log				3	1	4										1	2	3	4	3	7
22. Frontalin + resin				1		1										4	4	8	5	4	9
23. Frontalin + α-pinene					3	3										1	3	4	1	6	7
24. Frontalin + Mix. D		1	1		2	2				1		1				2		2	3	3	6
25. Frontalin + Mix. D																1	4	5	1	4	5
26. Frontalin + camphene				2	6	8										5	8	13	7	14	21
27. Frontalin																1	6	7	1	6	7
28. α-pinene					3	3											1	1		4	4
29. Camphene				7	5	12										1	4	5	8	9	17
30. Check				3	5	8										3	1	4	6	6	12
TOTAL		1	1	16	25	41				1		1				19	33	52	36	59	95
GRAND TOTAL	28	20	48	16	25	41	22	25	47	38	45	83	9	30	39	20	35	55	133	180	313

[1]See table 2 for composition of mixtures and sources of supply.

Table 11.--*Numbers of the most abundant species caught, by location*

Location[1]	Trap days	Douglas-fir beetle	*Enoclerus sphegeus*	*Dendroctonus valens*	*Ips pini*
1	3	318	6	5	1
2	6	906	303	172	428
3	3	620	3	3	1
4	3	40			
5	3	32	1	2	
Total		1,916	313	182	430

[1]See table 1.

RESPONSE OF OTHER BARK BEETLES

Eleven genera and 24 species of bark beetles were caught (table 4). Besides the Douglas-fir beetle, six species merit discussion because of their abundance or sex ratios.

Numbers of *Ips pini* were fairly constant by sex and treatment groupings (tables 6, 12). It was abundant only in Location 2, probably because its host, ponderosa pine, was felled among the traps there. Only two specimens were caught elsewhere. Further, it was the most abundant species caught on the check traps. We see no apparent involvement of any of our treatments in its aggregation. The low catch by traps baited with ♀ logs indicates that they may have repelled *I. pini*.

Numbers of *D. valens* caught by treatments did not differ significantly. However, treatments involving frontalin attracted generally more males than females and no beetles were caught by check traps. Similarity of these results to those of the Douglas-fir beetle indicate that a low level attraction may have occurred.

The next most abundant species were *Hylastes nigrinus* and *Hylastes ruber*. Their sex ratios did not differ. However, significantly more females were caught of the next two most abundant species, *Hylurgops porosus* and *Hylurgops* n.sp. They were not attracted by any particular treatment, except for *Hylurgops* n.sp. On May 21, 17 female *Hylurgops* n.sp. were caught by a trap baited with a ♀ log. The catch of *Hylurgops* n.sp. on other traps during the test never exceeded four, usually only one or two were caught, if any.

Conclusions

We infer from these tests that frontalin and resin (including some of its monoterpenes, especially α-pinene) are important, but they are not the only components of the aggregating mechanism of *D. pseudotsugae*. Baiting of live trees with any of the more productive treatments will likely induce attacks by wild beetles which themselves add attraction and cause mass attack. However, use of baited mechanical traps of any sort for control would be enhanced by additional naturally occurring attractants, not yet identified. These attractants are presumed to be pheromones rather than host volatiles.

Comparison of catches of *D. pseudotsugae* and its beetle predators indicates that the aggregating mechanism of the former is more specific to it than its enemies. Deployment of such specific attractants for control of the Douglas-fir beetle may leave predators relatively unscathed to carry on their work of controlling beetles that fail to be trapped.

Table 12.--*Number and sex of other scolytids caught by treatment, Boise Basin Experimental Forest, 1970*

Treatment[1]	*Dendroctonus valens* ♀	*Dendroctonus valens* ♂	*Dendroctonus valens* Σ	*Ips pini* ♀	*Ips pini* ♂	*Ips pini* Σ
GROUP I						
1. Camphene	2	1	3	2	2	4
2. Limonene	3	4	7		3	3
3. α-pinene	1	1	2	5	5	10
4. β-pinene	2	3	5	12	9	21
5. Mix. B	4	3	7	2	3	5
6. Resin	4	4	8	17	22	39
7. Myrcene	3	1	4	4	4	8
8. Mix. A	6	2	8	5	5	10
9. 3-carene				4	4	8
10. Mix. C	4	6	10	21	20	41
TOTAL	29	25	54	72	77	149
GROUP II						
11. Frontalin + resin	1	2	3	7	8	15
12. Frontalin + α-pinene		2	2		1	1
13. Frontalin + limonene	2	2	4	17	19	36
14. Frontalin + myrcene	6	14	20	6	6	12
15. Frontalin + β-pinene	4	10	14	1	3	4
16. Frontalin + Mix. B	3	8	11	5	6	11
17. Frontalin + Mix. C		5	5	17	6	23
18. Frontalin + Mix. A	2	4	6	8	3	11
19. Frontalin + camphene	1	1	2	6	1	7
20. Frontalin + 3-carene	7	7	14	5	6	11
TOTAL	26	55	81	72	59	131
GROUP III						
21. 50 ♀♀ log	1	2	3	1	2	3
22. Frontalin + resin	1	2	3	7	5	12
23. Frontalin + α-pinene	2	1	3	15	6	21
24. Frontalin + Mix. D	2		2	4	5	9
25. Frontalin + Mix. D	4	10	14	6	7	13
26. Frontalin + camphene	3	6	9	12	11	23
27. Frontalin		1	1	17	16	33
28. α-pinene	1	2	3	4	3	7
29. Camphene	2	7	9	5	7	12
30. Check				6	10	16
TOTAL	16	31	47	77	72	149
GRAND TOTAL	71	111	182	221	208	429

[1]See table 2 for composition of mixtures and sources of supply.

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